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ADHD, Lead, and PCBs: Appropriate Comparison Studies

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In their article "Lead and PCBs as Risk Factors for Attention Deficit/Hyperactivity Disorder" (ADHD), Eubig et al. (2010) offered a large compilation of human and animal research supporting a relationship between these environmental contaminants and ADHD occurrence. Key to understanding such a relationship, however, is research quality, not quantity.

As Eubig et al. (2010) noted, ADHD is highly heritable, a history of ADHD in a parent or sibling being a strong predictor of ADHD occurrence in a child (Faraone and Doyle 2001). A sound study of the disorder and lead or polychlorinated biphenyls (PCBs) would therefore control for family history. The authors listed seven studies of lead exposure and ADHD in their Table 2, but five of the studies had no information on family history so they could not answer the question of a relationship. Another study suffered from likely underascertainment of parental history; even so, it remained significantly ($p < 0.01$) associated with ADHD in case children (Wang et al. 2008). The last study controlled for familial neuropsychiatric disease and reported no significant association of children's blood lead levels (BLLs) and ADHD, despite its ample cohort size of $\geq 1,700$ (Ha et al. 2009).

In their Table 1, Eubig et al. (2010) listed 12 studies of human lead exposure and performance on test functions impaired in ADHD. Only 3 of the studies considered heritability as a possible confounder of this relationship, but none reported an association with performance (Chiodo et al. 2004, 2007; Stewart et al. 2006). This is surprising, given the marked heritability of ADHD, and raises the question of how well individual test functions may control for or serve as surrogates of ADHD diagnosis per se. Also, Stewart et al. (2006) found only a marginal ($p < 0.047$) association with medical record information on postnatal BLL in a potentially biased 60.9% of subjects, and no association ($p < 0.641$) with umbilical cord BLL in 88.6% of subjects.

According to National Health and Nutrition Examination Survey (NHANES) data, the proportion of elevated BLLs ($\geq 10 \mu\text{g}/\text{dL}$) in U.S. children 1–5 years of age dropped from 77.8% in 1976–1980 to 0.9% in 2005–2008 (Centers for Disease Control and Prevention 2005; HealthyPeople.gov 2011). However, the occurrence of ADHD and its diagnostic predecessors has been rising

since the 1980s, if not before, offering no support for a positive association of BLL with ADHD (Pastor and Reuben 2008).

The PCB literature Eubig et al. (2010) presented in their Table 4 provided a picture little different from that of lead. PCB exposure is also apparently trending downward (Tee et al. 2003).

The dearth of well-controlled studies leaves open Eubig et al.'s question whether lead or PCBs exert an effect on ADHD occurrence beyond that exerted by heritability. This question cannot be answered satisfactorily until researchers consistently impose adequate control in their studies and funding agencies consistently require such control in the research they support.

The author has no actual or potential competing financial interests.

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ADHD, Lead, and PCBs: Eubig et al. Respond

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In response to Brondum's comments we would like to reiterate that the main purpose of our review (Eubig et al. 2010) was to examine the parallels between cognitive domains affected in children with attention deficit/hyperactivity disorder (ADHD) and domains shown to be affected in human and animal studies of developmental exposure to lead and polychlorinated biphenyls (PCBs), two environmental contaminants for which a relatively large body of literature exists. In doing so we hoped to explore the possible role of exposure to environmental contaminants in the variable phenotypic expression of ADHD, and to stimulate interest in further research in this area.

In our review, we did not seek to identify individual behavioral tests or functional domains that could serve as surrogates for ADHD diagnosis. Nor did we make the case that developmental lead and PCB exposure are responsible for the rise in ADHD diagnoses in recent years. To the contrary, in our section on other environmental contaminants we specifically highlighted the fact that PCB and lead exposures are declining, whereas exposures to other chemicals—including brominated flame retardants, bisphenol A, phthalates, polyfluoroalkylated compounds and certain pesticides—are increasing. We note that studies of the potential role of these emerging contaminants in the etiology of ADHD are equally, if not more, important than further studies of lead and PCBs. In addition, there is a clear difference between exploring contaminants as potential contributors to ADHD risk as opposed to causing ADHD. Examining our Table 6 (Eubig et al. 2010), which showed a comparison of the strength of the evidence for cognitive domains affected in ADHD with domains affected in developmental lead and PCB exposure, should convince the reader that these three conditions are similar but not the same. Brondum seems to miss this point in implying that our review is without value because the studies that evaluated the association between lead and a diagnosis of ADHD, which comprise a relatively small part of our review, are flawed in his opinion.

No one is debating whether parental psychopathology should be considered as a possible confounding factor in studies that examine the association of contaminant exposure with specific neurobehavioral diagnoses, including ADHD. Braun et al. (2007)

acquiesced to that point in a reply to the first of several letters to the editor by Brondum (2007) on the same topic. However, Braun et al. (2007) noted that including such information is not always possible when, for example, the use of National Health and Nutrition Examination Survey (NHANES) data or other constraints on study design do not allow it. Although we agree that failure to control for parental psychopathology is a weakness in many of the published studies reporting an association between childhood lead exposure and a diagnosis of ADHD, we believe that the consistency of the association across several published studies using different study designs adds to the weight of evidence that this is a real association and not a spurious effect due to uncontrolled confounding.

We hope that this reply clarifies the goals of our review for those faced with the challenge of assessing the neurobehavioral effects of emerging contaminants and their possible contribution to the phenotypic expression of ADHD or other neurodevelopmental disorders.

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Home Energy-Efficiency Retrofits

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In the February 2011 issue of *EHP*, Manuel (2011) took an important look at some potential adverse health implications of home energy retrofits. Here, we further discuss the complexity of possible indoor environmental concerns and encourage incorporation of comprehensive homeowner education campaigns in weatherization programs.

The reduction of air infiltration by air sealing is a common energy retrofit measure (McCold et al. 2008). Several field studies of weatherized homes have reported average reductions in air leakage of 13–40% (Berry 1997; Judkoff et al. 1988), although the impact of weatherization on actual air

exchange rates and indoor pollutant concentrations is poorly understood. Moreover, studies have seldom evaluated the effects of weatherization on low-income groups or vulnerable populations (e.g., asthmatic or elderly), although occupants in low-income residences are at higher risk for many indoor environmental hazards (Evans and Kantrowitz 2002), and some population subgroups may also be disproportionately affected by indoor air pollution (Hun et al. 2009).

Although some research exists on the impact of weatherization on indoor concentrations of combustion products, radon, and moisture, other indoor pollutants deserve attention. For example, Logue et al. (2011) identified nine priority indoor air pollutant hazards in U.S. residences, which, among others, have been associated with a wide range of both chronic and acute health effects (e.g., benzene, 1,4-dichlorobenzene, formaldehyde, naphthalene, particulate matter < 2.5 µm in aerodynamic diameter). Moreover, reducing air exchange rates in residences will likely increase indoor concentrations of reactive pollutants and the probability of chemical reactions occurring between them indoors (Weschler and Shields 2000), generating by-products associated with respiratory symptoms and asthma, such as low-molecular-weight aldehydes, dicarbonyls, and secondary organic aerosols (Jarvis et al. 2005). On the other hand, reductions in air infiltration should decrease penetration of outdoor pollutants, which is of particular importance in traditionally leakier low-income households (Chan et al. 2005) in neighborhoods with high outdoor air pollution. Thus, we urge the environmental health community to investigate the net effects of weatherization on a wide variety of indoor and outdoor pollutants and health outcomes.

Implementation of home energy retrofits also creates an opportunity to incorporate innovative, engaging homeowner education strategies to reduce both energy consumption and indoor environmental risks. Occupant behavior has a major influence on both energy consumption (Allcott and Mullainathan 2010) and indoor exposures to pollutants (Meng et al. 2005). Furthermore, many indoor air quality risks can be mitigated with relatively simple home behavior practices, such as using exhaust fans, avoiding toxic cleaning chemicals, and using appropriate air cleaners (Brugge et al. 2003). However, we have learned from research on household energy consumption that educational materials alone usually fail to alter behaviors (Charles 2009). Greater energy savings from home retrofits could be achieved by complementing homeowner education campaigns with regular feedback on energy use and economically motivational programs

(Peschiera et al. 2010). Additionally, home walkthroughs with trained building specialists can identify energy-inefficient behaviors and appliances in conjunction with potential indoor environmental hazards. These and other behavior-change strategies to promote green and healthy housing should be made available to weatherization programs across the country, and their effectiveness should be assessed. Because home weatherization is currently a priority of the federal government, this is a crucial time to address these fundamental research questions and implement the findings nationwide.

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